A STUDY OF METAZOAN PARASITES FOUND IN THE PHILADELPHIA ZOOLOGICAL GARDENS.

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The first part of this communication deals with certain statistics regarding *all* the parasitic worms found in the Gardens; the second, with separate species which have been of economic, scientific, or passing interest.

PART I.

The statistics which follow have been compiled from autopsy protocols at the Laboratory of Comparative Pathology of the Philadelphia Zoological Gardens. The autopsies number 2,807, and extend from November 25, 1901, to January 1, 1913. They were performed with care, especially those on the larger animals. All mammalia and aves dying were examined. Only a few of the reptilia received attention. The organs were not extensively dissected or examined microscopically. They were closely scrutinized grossly, and if occasion warranted microscopical sections were made. For these reasons many of the smallest parasites have been missed, and this may explain the small number of flukes appearing in. our tables.

The table opposite shows roughly an average of (excluding 1901–1905, when the parasites were not especially searched for) 45 infestations per year. In 1910 there was a rise due to cestodes in birds, and again a rise in 1911 which we trace across to nematodes—again in birds. Referring to the General Parasitological Table II, nematode column, we find that of the aves it is the Psittaci and Passeres which are responsible for the latter rise. Our detailed Psittaci records now lead us to a certain worm, *Spiroptera incerta*. This worm was apprehended, however, long before these tables were compiled. This table led us to investigate the Passeres which show 33 nematodes. A coiled *Filaria* in the *serosa* of the proventricle was revealed. We propose to investigate it in the near future. It is probably *Filaria pungens*.

Table I is more of local than general scientific value. It shows the incidence of parasites by years, and enables us to trace to its source any special increase of infestation that may occur in the Gardens.

GENERAL PARASITOLOGICAL TABLE I.

SHOWING INFESTATION BY ALL PARASITES BY YEARS.[1]

	Nematodes.	Acanthocephalus.	Cestodes.	Trematodes.	Unclassified.	Total.
1901–1904:						
Mammalia	6	....	3	....	1	
Reptilia	....	....	....	....	....	
Aves	....	....	1	....	....	
Total	— 6	....	— 4	....	— 1	11
1905:						
Mammalia	11	....	6	....	7	
Reptilia	2	....	....	....	....	
Aves	9	....	1	....	16	
Total	— 22	....	— 7	....	— 23	52
1906:						
Mammalia	12	....	1	....	....	
Reptilia	1	....	1	....	....	
Aves	21	....	2	3	1	
Total	— 34	....	— 4	— 3	— 1	42
1907:						
Mammalia	4	....	6	....	....	
Reptilia	3	....	1	....	....	
Aves	26	....	5	....	1	
Total	— 33	....	— 12	....	— 1	46
1908:						
Mammalia	5	....	8	....	....	
Reptilia	....	....	....	....	....	
Aves	29	2	2	....	....	
Total	— 34	— 2	— 10	....	....	46
1909:						
Mammalia	18	....	5	....	2	
Reptilia	2	....	....	....	....	
Aves	19	....	1	....	....	
Total	— 39	....	— 6	....	— 2	47
1910:						
Mammalia	18	....	7	1	....	
Reptilia	....	....	1	1	....	
Aves	14	....	15	....	....	
Total	— 32	....	— 23	— 2	....	57
1911:						
Mammalia	12	....	7	....	2	
Reptilia	2	....	....	....	....	
Aves	50	....	5	3	....	
Total	— 64	....	— 12	— 3	— 2	81
1912:						
Mammalia	12	....	6	....	....	
Reptilia	....	....	....	....	....	
Aves	25	....	9	1	....	
Total	— 37	....	— 15	— 1	....	53
	301	2	93	9	30	435

[1] The years referred to are the fiscal years of the Gardens ending March 1, except the last—1912—which we have made to end on January 1, 1913.

GENERAL PARASITOLOGICAL TABLE II.
SHOWING AVIAN ORDERS AFFECTED.

Aves.	Nematodes.	Acanthocephalus.	Trematodes.	Cestodes.	Unclassified.	Total.
Alectorides	1	......	......	......	......	1
Columbæ	6	......	......	2	......	8
Picariæ	6	......	......	2	1	9
Gaviæ	1	......	......	......	......	1
Steganopodes	1	......	......	......	......	1
Fulicariæ	1	......	2	......	3	6
Striges	1	......	......	......	1	2
Psittaci	114	......	......	2	2	118
Herodiones	16	......	5	2	2	25
Galli	6	......	......	3	1	10
Anseres	......	2	......	5	1	8
Accipitres	6	......	......	......	......	6
Limicolæ	1	......	......	......	......	1
Passeres	33	......	......	25	7	65
Total	193	2	7	41	18	261

GENERAL PARASITOLOGICAL TABLE III.
SHOWING MAMMALIAN ORDERS AFFECTED.

Mammalia.	Nematodes.	Acanthocephalus	Trematodes.	Cestodes.	Unclassified.	Total.
Primates	18	......	......	1	4	23
Lemures	3	......	......	3	......	6
Carnivora	41	......	1	21	2	65
Ungulata	8	......	......	11	2	21
Rodentia	6	......	......	8	3	17
Marsupialia	21	......	......	3	1	25
Edentata	1	......	......	1	......	2
Hyraces	......	......	......	1	......	1
Total	98	......	1	49	12	160

Table III shows that of mammals the Carnivora are by far the most heavily infested order. Primates, Ungulata, and Marsupialia are about even for second place.

GENERAL PARASITOLOGICAL TABLE IV.
SHOWING REPTILIA AFFECTED.

	Nematodes.	Acanthocephalus	Trematodes.	Cestodes.	Unclassified.	Total.
Reptilia	10	......	1	3	......	14

The data on reptiles are not of value on account of the small numbers, but are included here for the sake of record.

GENERAL PARASITOLOGICAL TABLE V.
SUMMARY.

	Nematodes.	Acanthocephalus.	Trematodes.	Cestodes.	Unclassified.	Total.
Mammalia	98	......	1	49	12	160
Aves	193	2	7	41	18	261
Reptilia	10	......	1	3	......	14
Totals	301	2	9	93	30	435

The summary shows, as to the relative numbers of worms, that nematodes are far the commonest; then come the cestodes, flukes, and Acanthocephali in order named. This is the usual order given in text-books. It seems, however, that our summary shows too great a disproportion between the nematodes and cestodes, due doubtless to the endemic of nematode *Spiroptera* in the parrots. Excluding those, a ratio of two nematodes to one cestode is obtained. This would appear to express about the proper relationship, which now holds good in both birds and mammals.

Tables have also been made showing the location of the parasites in the different mammalian and avian orders, and in reptiles, as follows:

GENERAL PARASITOLOGICAL TABLE VI.
SITE OF INFESTATION.

Aves.	Trachea.	Esophagus.	Proventricle.	Gizzard.	Intestine.	Ceca.	Cloaca.	Liver.	Kidney.	Lung.	Air Sacs.	Skin.	Peritoneum.	Blood.	Total.
Alectorides					1										1
Columbæ			5		3										8
Picariæ			6	1	2										9
Gaviæ			1												1
Steganopodes		1													1
Fulicariæ			1					3			2				6
Striges					2										2
Psittaci			109	4	4									1	118
Herodiones			11		8		1	1		1		1	4		27
Galli	1		2		6	1									10
Anseres			2		6										8
Accipitres			2		1						1		1	2	7
Limicolæ			1												1
Passeres			9	1	30			1	1	1	6		9	10	68
Totals	1	1	149	6	63	1	1	5	1	2	9	1	14	13	267

Six duplications, *i.e.*, more than one parasite found in different organs of same bird.

General Parasitological Table VII.

Mammalia.	Intestine.	Stomach.	Lungs.	Muscle.	Blood.	Liver.	Pancreas.	Not given.	Peritoneum.	Kidney.	Pericardium.	Bronchi.	All Tissues.	Aorta.	Frontal Sinuses.	Total.
Primates	5	3	2	......	2	......	1	......	10	......	......	1	......	......	......	24
Lemures	3	1	1	......	......	1	......	......	1	......	1	......	......	......	......	8
Carnivora	47	9	2	6	1	......	......	......	......	......	......	......	1	1	1	68
Ungulata	8	2	3	......	......	2	......	......	7	1	1	1	......	......	......	25
Rodentia	11	......	......	......	......	1	1	1	3	......	......	......	......	......	......	17
Marsupialia	6	18	1	1	1	......	......	......	......	......	......	......	......	......	......	27
Edentata	2	......	......	......	......	......	......	......	......	......	......	......	......	......	......	2
Hyraces	......	......	......	......	......	1	......	......	......	......	......	......	......	......	......	1
Totals	82	33	9	7	4	5	2	1	21	1	2	2	1	1	1	172

Twelve duplications.

General Parasitological Table VIII.

	Intes-tine.	Stomach	Lungs.	Cloaca.	Perito-neum.	Total.
Reptilia	8	2	3	1	1	15

One duplication.

General Parasitological Table IX.
Summary of Location of Parasites.

	Intestines.	Stomach.	Proventricle.	Ceca.	Bronchi.	Air Sacs.	Peritoneum.	Kidney.	Frontal Sinuses.	Esophagus.	Aorta.	Liver.	All Tissues.	Lung.	Trachea.	Cloaca.
Mammalia	82	33	......	......	2	......	21	1	1	......	1	5	1	9	......	......
Reptilia	8	2	......	......	......	......	1	......	......	......	......	......	......	3	......	1
Aves	63	......	149	1	......	9	14	1	......	1	......	5	......	2	1	1
Totals	153	35	149	1	2	9	36	2	1	1	1	10	1	14	1	2

Number of duplications, 19.

	Not given.	Pericardium.	Gizzard.	Blood.	Skin.	Muscles.	Pancreas.	Total.
Mammalia	1	2	......	4	......	7	2	172
Reptilia	......	......	......	......	......	......	......	15
Aves	......	......	6	13	1	......	......	267
Totals	1	2	6	17	1	7	2	454

In the summary, Table IX, the accepted predominance of intestinal parasites is shown. The next most frequently affected organ is the stomach. The peritoneum comes next, due to the presence of Filariæ, which also account for the fourth position of the blood.

Part II.

Spiroptera incerta (Smith).

This worm has been encountered 119 times, as follows:

Table X.

Parrots	102
Blue-headed Pigeons	3
Ashy-headed Barbet	1
Banded Toucan	2
Green glossy Starling	1
Sulphur-breasted Toucan	2
Barbary Turtle Dove	1
White-crowned Pigeon	1
White-throated Quail	1
Transvaal Barbet	1
Himalayan Jay	1
Double-striped Thicknee	1
Natal Francolin	1
Larger hill Mynah	1
	119

Since the greatest number occurred in parrots, our attention has been especially called to those birds. In fact, our work on this parasite of parrots has constituted by far the greatest part of our studies in metazoan parasitology at the Gardens.

The appended table shows the exact findings since March 1, 1906:

Spiroptera Table XI.

Deaths from Spiroptera among Psittaci.

Year ending.	Verminous.	Not verminous.	Total from all causes.	Per cent. dying with worms.	Total number of Psittaci in collection.
Mar. 1, 1906.....	3	45	48	6	Not obtainable
Mar. 1, 1907.....	16	29	45	6	" "
Mar. 1, 1908.....	17	36	53	32	" "
Mar. 1, 1909.....	20	16	36	56	" "
Mar. 1, 1910.....	10	30	40	25	" "
Mar. 1, 1911.....	12	29	41	29	132
Mar. 1, 1912.....	24	57	81	30	139
Jan. 1, 1913.....	11	26	37	36	137
Total.....	113	268	381	30	408

As will be noted, an average of 30 per cent. of all parrots coming to autopsy harbored these worms. Is it the parasite which has caused death, or is this simply an example of commensalism which is so common in the lower animals?

We find (consulting our Table XI) that the percentage of birds dying with worms is fairly constant, except for the year ending 1909, and excluding 1906 when the cases were beginning to be recognized. This would indicate at first sight that the verminous cases were only incidents, that 30 per cent. of our birds had harmless worms which appeared at autopsy when the bird died from intercurrent disease.

To throw further light on the subject a curve was prepared showing deaths of Psittaci by months. Again there is a rough parallellism between the curves of verminous and non-verminous birds. The charts then would exculpate the parasite.

Now let us consider the opposed evidence. It will be brought out later that we have examined every parrot in the parrot-house and found 14 per cent. of our living parrots verminous. What does this mean? Correlating this finding with our statistics, we have established two facts:

(1) 14 per cent. of our living parrots are verminous.

(2) 30 per cent. of all parrots dying in a year are found verminous. See *Spiroptera,* Table XI.

A greater percentage (in fact, proportionally twice as many) of our verminous birds die as do non-verminous. To consider a specific instance, suppose our bird-house contain 140 live parrots—

A. From (1) above, 14 per cent. of our living parrots would be verminous, 20 birds.

B. 86 per cent. of our living parrots would be non-verminous, 120 birds.

Suppose at the end of the year there had been 50 deaths (average for 7 years).

C. From (2) above, 30 per cent. would be verminous, 15 birds.

D. Then 70 per cent. would be non-verminous, 35 birds.

From A and C—Out of 20 living verminous birds 15 deaths resulted, 75 per cent.

From B and D—Out of 120 living non-verminous birds 35 deaths resulted, 30 per cent.

The mortality is more than twice as great for living verminous parrots than for non-verminous.

This is one point against the innocence of *Spiroptera incerta.*

Our second witness is the autopsy picture.

The Parasite.—It has been described in detail by Dr. Allen J. Smith as a new species in his *Synopsis of Studies in Metazoan Parasitology.* Briefly, the mature female averages 14 mm. in length by 0.6 mm. in diameter. It is rigid, of a dead or yellow-white color. The male is distinctly smaller. They vary in numbers from two to a hundred or more. The usual number is twenty or thirty. They may be found in a ball of mucus in the lumen of the proventricle or burrowing into the mucosa. The smallest (larval) forms are often found under the thick chitinous lining of the gizzard.

The Host.—In severe infestations the bird is emaciated. It sometimes emits a wheezing sound (not pneumonia) or passes mucus from mouth or nostril. Often the droppings have been abnormally copious, and when mucus is admixed (as it often is) infestation has been foretold.

The Lesion.—Even where there are but a few worms (4–6) in the proventricle, the swelling is prominent. Diagnosis can be made as soon as the body cavity is opened. On opening the organ the mucosa is found necrotic and overlaid by mucus. The worms, if pulled out by forceps and relaid on the mucus promptly burrow into it and disappear. Where the worms are numerous the viscus is enormously distended, even exceeding the gizzard in size. The heart is pushed far to the right, the gizzard placed so low as to press on the cloaca. In one case a perforation had occurred, and seeds and worms were found in the air sacs. On section the mucosa is necrotic, destroyed. The wall of the viscus may be so thin as to be translucent. The

lumen is occluded by the necrotic and mucoid débris. Microscopically the mucosa is in part or wholly necrotic and the parasite may be found burrowing even close to the muscularis. The only reactive inflammation seen is around the nerves, where a round-cell infiltration sometimes occurs.

Necrogenesis.—From the clinical and postmortem findings it would seem that a variety of agencies are operative in causing death. Where the parasites are in small numbers in a large bird they are probably not the cause of death. Occlusion of the proventricular lumen probably plays a minor part by retarding food ingestion. Much more important is the destruction of the mucosa of this (for birds) important digestive organ. In fact, it has been called the glandular stomach in contradistinction to the muscular stomach or gizzard. This probably accounts for the emaciation seen clinically. Theoretically, this worm might elaborate a toxic material, as does the fish tapeworm of man, which may act as an irritant on important vital organs. Such irritation was seen in a chronic form around nerves in one of our microscopic sections. Displacements of organs noted above (heart by pressure, gizzard by weight of superjacent proventricle) could easily contribute to the end. It is our belief at present that only a part of the cases listed as verminous died as a result of spiropteriasis: that the cases showing a few worms and not much tissue destruction died from intercurrent diseases, but that others, those so greatly emaciated, with occluded lumina, pressure upon the heart and destruction of mucosa, undoubtedly died as a result of the presence of these worms.

Our autopsy shows alterations of important structures, extensive enough and serious enough to incriminate the parasites in spite of the evidence of our tables and charts. This fact, considered with Spiroptera Table XI, shows the worm to be of economic importance.

In studying this endemic we have worked along three lines:

I. To devise a practical method whereby infested birds might be discovered and isolated.

II. To determine the life history of the worm. This is most important from a hygienic and prophylactic standpoint.

III. To discover a therapeutic agent.

Diagnosis.

We feel that we have been successful in our first task. The external appearances were never sufficiently characteristic to lead to exact diagnosis. Some birds, even though passing enormous

numbers of ova, were in good feather. Others showed symptoms like any sick bird—feathers ruffled, head hung down, eyes closed. Several cases, however, showed suggestive symptoms. They extended the neck as though attempting to vomit. A macaw passed a frothy material from the mouth. Another bird which did not have pneumonia emitted a wheezing sound. Some of the birds produced droppings in larger quantity than their mates, and where these contained mucus, as they often do, we have foretold infestation. But these signs were so inconstant that laboratory diagnosis became necessary.

The only avenues to diagnosis would seem to be the blood, urine, droppings, stomach contents, and temperature. Some time has been spent investigating the blood, but so many technical difficulties arose and so much time was required that this means was abandoned.

Experiments were also performed toward the production of emesis and the recovery of the worms in the vomitus. Preliminary experiments on pigeons were successful. One-tenth of a grain of apomorphine hypodermically caused regurgitation of food. This was probably only from the crop, as no stones accompanied the grain. An amazon received one-fifth of a grain of apomorphine hypodermically. Excited talking, laughter, and some dizziness resulted, but no emesis.

An attempt was then made to draw out the proventricular contents mechanically. This failed, as a small catheter used as a stomach-tube could be introduced only as far as the crop, as demonstrated upon a dead parrot.

The urine is evidently useless for diagnosis when we consider the anatomy of the avian excretory apparatus. Temperature determinations would require manipulations which the smaller birds could not stand.

The droppings remain as our sole means of diagnosis. The parasitic ova are not easily found. The excreta of birds contain more waste than human dejecta, where everything is generally in a finely granular condition. The droppings are laden with such quantities of vegetable cells, colored by chlorophyl, that they quite hide the ova unless the latter are in such great numbers as not to be lost by high dilutions. Efforts to dissolve this foreign matter have been ineffectual. It was not digested by pancreatin overnight in an incubator. Boiling with antiformin, while ineffective, broke up the cloddy particles of the droppings, clarified the vegetable cells, and dissolved the mucus and urates. Much of the chlorophyl was extracted. Our

routine practice is now to boil droppings for five minutes in 10 per cent. potassium hydroxide, shake one minute, boil three minutes, centrifuge for one minute. Two portions of the sediment are examined for ova under the $\frac{2}{3}$ lens, one from the surface and one from the bottom. The preparation of each specimen examined in lots of ten requires five minutes. The examination under the lens requires ten minutes where no ova are present. When present they are detected usually in less than one minute, although one case was diagnosed only after eight minutes. The total time for examining one bird is thus fifteen minutes. A mechanical stage is used and the entire wet specimen is gone over.

With a view to decreasing the amount of débris, the birds have been starved for twelve, in the case of smaller birds, or, in the case of larger ones, twenty-four hours. The droppings are collected during the subsequent twelve hours. That this is a necessary procedure has been shown in subsequent examinations of these same birds where they have not been starved. In every case the eggs are more concentrated where the bird has been starved. This was shown practically in the case of a green-cheeked amazon which was passed as not verminous during our preliminary experiments without starving, but detected after starving.

Employing the method outlined above (for convenience called "the improved method"), every bird in the parrot-house was examined. The birds were first moved to a separate building. The parrot-house was then thoroughly fumigated with formaldehyde, the cages galvanized and new stands erected. Birds whose droppings showed ova were isolated in the infirmary. The others were sent to the parrot-house. Those removed to the infirmary were again examined by improved method without starving, to guard against a possible clerical error by which the specimens might have been mixed.

As a result of the examination of all of our parrots, twenty were detected and isolated (14 per cent.). These twenty birds have been used for subsequent experimentation. Some, too, have been kept in an open cage exposed to the weather. For these reasons it is unfair to compare the mortality of these verminous birds with that of the non-verminous at the parrot-house. If such a comparison could be fairly made it would furnish valuable evidence regarding the criminality of the worm, as discussed earlier in this paper.

As these birds died they were posted, and in all cases the worms were found in the proventricle. We have found that our technique

is very accurate. Mexican conure (P. Z. G. No. 2,599) showed at autopsy a solitary female and a solitary male worm, yet it was detected, January 31, 1912. Two ova in one slide. We have been particularly gratified by the subsequent showing of the parrot-house. Out of 23 birds dying during the last nine months, not one has shown worms.

Life History.—The determination of the life cycle of this worm would be of scientific and prophylactic value. In only one, *Spiroptera sanguinolenta,* has the life cycle been worked out. From a hygienic standpoint, such a determination would be valuable by ascertaining:

1. Mode of transmission from bird to bird.
2. Time elapsing between ingestion of ovum and development of sexually mature female.

As long as we have to rely upon finding ova in the droppings, we will not be able to detect those birds with immature worms. If we can determine the time elapsing between ingestion of egg and maturity of female we will have determined the period of time during which to quarantine new arrivals, who, while not showing ova in droppings, may nevertheless harbor immature worms. The determination of this point would also give us the intervals at which to reëxamine the parrots which have been passed as healthy to the parrot-house. In the absence of this knowledge we run a certain risk. Future reëxaminations will have to be made at quite arbitrary intervals until this developmental period is determined. Now that each inmate of the parrot-house has been examined and passed, any cases developing or dying there with worms will throw new light on the subject.

We have inquired into the life history of the worms by trying to grow them in artificial media and in experimental birds.

Ova from proventricular slime of a bird dead with *Spiroptera* were placed in various nutrient media (bouillon, condensation water of blood serum media), tap water, and weak alkaline and acid solutions. These were kept at various temperatures. One series at room temperature, another at 37.5°, and a third at the temperature of a bird's body (41°). They were examined daily. On the sixth day larval worms could be seen issuing from the eggs in tap water at room temperature. They did not hatch in the acid solution, but did appear sporadically in the other solutions at room temperature. The larvæ may be extruded either through the side or the end of the egg. One wonders how so large a worm could be coiled

in such a small shell. The disappointing factor is the sluggish action of the larva. It is encased in a well-marked sheath and while hatching has a languid swaying motion. When hatched its motion is scarcely more than a quiver. By the time it has been hatched an hour all motion has ceased. Beyond this stage we have seen no development. In 10 to 14 days the worm grows paler, faintly granular and disintegrates.

Supposing that some agent was necessary to dissolve the sheath and liberate the larva, weak solutions of HCL and sodium bicarbonate were applied, but to no avail. At the suggestion of Dr. Fox, an emulsion of parrots' proventricular mucosa was made and applied to the embryos. There was no development at room or incubator temperature.

The ova in the preceding experiments came from proventricular slime and had not received the action of the bird's intestinal canal. As soon as a bird was found with great numbers of fecal ova, they were washed out and the above experiments repeated in graded acids and alkalis, diluted pigeon serum, and tap water at room temperature and 41° C. The same results have been secured: they hatch best in tap water and serum at room temperature.

The most rapid hatching occurred in a corked vial of tap water at room temperature in which a female had been placed to deposit her eggs for subsequent experiments. Four days later she was found ruptured, her egg tubes protruding and also ruptured. In them were worms in all stages of hatching.

Animal Experimentation.

Three modes of transmission would seem to be possible:

1. Passage of egg into drinking water, and direct entrance of the egg to the host, as in the case of the common pinworm, *Oxyuris vermicularis.* This is the simplest possible cycle.

2. Passage into drinking water, a hatching or perhaps a moult or two, and then, by drinking or skin perforation, reinfestation, as seen in the hook-worm, *Necator americana.*

3. Passage of eggs into water or soil, ingestion by an intermediate host with moultings, passage from secondary host to water, and so back to definitive host, as seen among the flukes, *Fasciola hepaticum.*

A fourth mode, in which a biting insect might figure (as in filariasis) is surely ruled out, as no embryos have been found in either the peripheral or deep bloods of our verminous birds upon repeated examinations.

The first (direct) mode seems impossible for the following reasons:

A. In several cases we found infested birds whose cagemates were free.

B. Several pigeons were fed on eggs or actually had them placed in the crop by rubber tube and syringe. Killed at intervals of a month, proventricle and gizzard showed neither micro- nor macroscopic involvement. The last bird killed had been treated three months previously. Pigeons ought to be susceptible to these worms. Our records show that a Barbary turtle dove and white-crowned pigeon died with them in September, 1911, and three blue-crowned pigeons were similarly infested in September, 1907.

C. In order to get a perfect blood relationship, ova and embryos were placed in the crop of newly arrived parrots which had been tested by the improved method and passed. Another parrot was kept in a cage soiled by a verminous bird. One bird died in four weeks with pneumonia. It showed no worms. The others were examined regularly and so far have shown no ova in the stools.

D. Roseate cockatoo (No. 166) was placed in a cage with infested roseate cockatoo (No. 120) and drinking water allowed to become soiled on August 28, 1912. The birds were separated twelve weeks later and the healthy cockatoo found still healthy, as shown by examination of droppings.

In each of the four conditions cited above an opportunity was afforded for the ova to develop by the first mode. They failed to do so.

In testing out the second mode, embryo worms were fed to pigeons and parrots in the same way that eggs were administered in the preceding experiments. The pigeons were killed at one month intervals and the proventricle and gizzard examined by the microscope. No infestation was found. A roseate cockatoo also received the larva. In twelve months no ova have been found in the droppings upon repeated examinations. The remaining possibility—entrance by skin penetration—is now being tried.

The third mode which would involve an intermediate non-biting host, does not harmonize with our ideas of nematode transmission. In only one case, that of *Spiroptera sanguinolenta* of the dog, could I find such an example. The cockroach is the secondary host here, and as our aviary harbored many such insects, attention was directed to them. They were fed on cornstarch into which spiroptera ova were mixed. The roaches were dissected at intervals of two days, and though the eggs were found in the cloacal contents, no develop-

ment was ever made out. The tissues of the body cavity were also teased and examined with negative results.

Our work on the life history of this worm, then, has been disappointing. Aside from negative findings, we have only established the fact that the eggs may hatch in four days in tap water at room temperature.

Therapeusis.

Theoretically, the prospect of a successful therapy is not bright. The worms live in the soft, juicy wall of a canal between the crop and gizzard. Sometimes they appear in the lumen of this canal, in which case they are always surrounded by thick, tenacious mucus. If they are pulled out of this with forceps and are laid on the mucus they at once bore into it. It protects them from any passing medicament, which is apt to have only a transient effect while on its way from the crop to gizzard. Those worms, which may be partly protruded into the lumen from the wall of the canal, can retract and retreat, even as far as the serosa, as shown in one of our museum specimens. The smallest worms are found under the thick, chitinous lining of the gizzard. We have used, therefore, drugs which act on the worms in the lumen (thymol by mouth) and by way of the blood (arsenic hypodermically). The arsenic used has been in the form of Fowler's solution and atoxyl. We determined the minimum lethal dose for pigeons and administered a corresponding dose to the verminous parrots.[1] No practical results have come from our efforts at therapy. Two interesting points, however, were secured: The parrots and pigeons withstood thymol and arsenic in enormous doses, compared weight for weight with man. The droppings of a parrot very heavily infested averaged for five days 182,000 eggs per diem. After a dose of thymol, on one occasion it passed 288,000 eggs in one single day.

Filaria fasciata n. sp.

In the last three years we have found six examples of filariasis in dead wild-cats. They may be found in the intermuscular fasciæ of any of the muscles of the body, but especially in those of the thigh muscles. They number from two to forty. They are coiled in a most intricate manner in the loose areolar tissue, but slip out rather easily upon slight dissection and traction. The animal is emaciated. Its blood swarms with embryos.

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[1] *Fortieth Annual Report of the Board of Directors of the Zoological Society of Philadelphia*, 1912.

The female is 25–30 cm. long, filariform, 0.5 mm. in breadth. The mouth is simple, unarmed, circular. There are no papillæ or other special features at the cephalic extremity. Head is continuous with the body. Caudal extremity straight, conical. Anus subterminal. Vulvar orifice immediately anterior to same.

The male measures 11 cm. in length. It closely resembles the female except the tail. This is strongly curved into three or four spiral turns. There are two unequal sharp spicules, the longer 70μ in length, the shorter 45μ. There are five pairs of closely placed preanal papillæ and one pair of postanal.

The still living embryos measure 280 to 330 microns in length by 4 in breadth. They have a delicate sheath, lashing motion, and no progression under cover slip. Not examined in hanging drop. Stained specimens exhibit blue spots at irregular intervals, not uniformly enough to be established as head or tail spots. They have been injected hypodermically into kittens with the expected result: no transmission after a lapse of five months.

It was at first thought, with our imperfect specimens, that we were dealing with *Filaria striata* (Molin). This worm is briefly described in Latin:

"Os inerme, minimum; corpus filiforme, longissimum, tenuissime transversim striatum; extremitas anterior crassior; et posterior obtusæ; extremitas caudalis maris laxe spiraliter torta, foveola ante apicem limbo cincta, septem papillis permagnis utrinque prœdita vagina breve tubulosa; penis brevissimus uncinatus; extremitas caudalis femine inflexa. Longit. mar. 4.5″ crassit. $\frac{1}{4}$‴. Longit. fem. 1′ 3″; crassit. $\frac{1}{3}$‴."

With the occurrence of another autopsy many specimens of both sexes were obtained. It is now certain that we have not here *Filaria striata* (Molin), although the size and habitat of the two are the same. The female might fall under the description given above for *striata*, but the following differences are seen in the male.

1. The tail is *strongly* coiled.
2. There are six pairs of papillæ.
3. There are *two* spicules.

The last difference especially would appear to warrant the naming of a new species.

Tropidocerca contorta n. sp.

Numerous worms were found in the proventricle of a concave-casqued hornbill, *Dichocerus bicornis* (P. Z. G. 2,640). The mucosa

was dotted closely by blood-red or blackish points, which were usually best seen on the serosa, but sometimes best through the mucosa. The latter was covered with a thick layer of viscid mucus. The red points numbered perhaps sixty or eighty. A slight degree of teasing with subsequent pressure over such a point expressed a blood-red translucent body which proved upon microscopical examination to be a worm. From its subglobular shape it was at first supposed to be a fluke, but under the microscope it soon revealed characteristics which placed it among the nematodes. Thirty or forty of these blood-red worms were expressed and examined before any fixative was applied, the material coming to hand very shortly after death.

All of these blood-red worms were found to be females. The camera lucida drawings, Plate IV, and measurements are from fresh unfixed specimens, which have been slightly flattened out by the weight of the cover slip. They were examined in normal saline solution. They showed no motion even upon gentle warming. The host had been kept at 10° C. for six to eight hours before autopsy and the parasites *in situ* at the same temperature overnight. This low temperature acting for twenty-four hours probably explains their quiescence.

No males could be found in the slime which so thickly covered the mucosa. After the females had been expressed the mucosa was teased into fine shreds and emulsified in normal saline solution. The sediment was washed in the centrifuge several times and from it eight males were recovered with the aid of the microscope. It would appear from this that the males occupy the same positions that the females do, *i.e.*, the proventricular crypts.

The largest specimen of the mature female measures 2.1 mm. long and 1.9 mm. broad. On account of the complexity of its coils it is impossible to measure the length of the body axis. They are of a blood-red color, both grossly and microscopically, except the gut tract, which contains molecular black material. This central blackened tract may be seen even grossly upon careful scrutiny. They are moderately resistant to pressure, the trauma of extraction never rupturing the organism. Ordinary cover-glass pressure will rupture them only when the mounting medium (normal saline) evaporates excessively.

The form of the mature female is extraordinary and occasioned the construction of the genus *Tropisuris* (Diesing), later changed to *Tropidocerca.* Before flattening the specimens appear (as shown

by Lieberkühn) in the form of a pumpkin. At one pole the head projects, at the other the tail. The cuticle is very thick, transparent, finely transversely striated and of a blood-red color. It is often projected in expansions as the coils of the worm tighten. As the head becomes retracted the cuticle forms a collar-like fold. In some specimens the head and tail have been retracted into the centre of the coil so as to become invisible. In others they project in a varying degree, but never to a greater distance than half the diameter of the worm. In such cases the projected part of the body measures 100 to 150 mc. in diameter, tapers slightly anteriorly, to end suddenly at the oral opening. (Plate IV, figs. 4, 5 and 8.)

The Gut.—The mouth is unarmed and round. It is succeeded by a dome-shaped buccal space which passes into a long œsophagus. The œsophagus is marked off from the buccal space by a well-defined ring. The walls of the œsophagus are very thick and composed of circular and radial muscle fibres. The œsophagus can be traced deeply into the coils of the worm, where it ends by a rounded extremity in the intestine. The intestine is visible only as a black, irregular tract which twists apparently with the coils. It commences as a large cul-de-sac which receives the œsophagus. It soon narrows and thereafter is irregular in size. Anus subterminal. (Plate IV, fig. 8.)

The posterior extremity of the worm narrows quickly to a sharp point. Anal opening 450 mc. from tip. Vulvar orifice 900 mc. from tip. Between the two openings the cuticle is thickened so as to produce a rounded swelling. (Plate IV, fig. 6.)

The general body cavity, including its expansions, is filled with closely packed egg tubes, suggesting that such expansions are especially designed to accommodate an extraordinarily developed reproductive system. From the specimens examined *in toto* the details of this system could not be made out.

The ova are elliptical, measure 40 to 45 mc. in length and 20 to 25 mc. in width. Several specimens showed a peculiar unilateral bib attached to the outside of the shell. (Plate IV, fig. 7.)

Attempts were made to determine a regular arrangement of the coils. This was very difficult in the case of the fully matured females. It would seem from their shape that the body expansions grew into the grooves between the coils so as to form a well-rounded mass. This makes it difficult to determine from which coil the head and tail protrude (if they protrude at all) and which coils are continuous with each other. The presence of the cuticular expansions only serves to increase the difficulty.

Immature females were not nearly so puzzling. It was through a consideration of the coils of different specimens at different stages of development, together with reconstructions in wax, that the arrangement of the twists was finally made out.

The sex of the youngest female could only be determined by its greater proportionate breadth. It measured 2.5 mm. in length and 0.2 mm. in width. It was found with the eight males mentioned above. It was cylindrical, colorless, and showed no internal structure. It was not coiled, but even at this early stage of development showed by its angulations a disposition to coil. (Plate IV, fig. 3.)

The next female studied in point of age was coiled in one plane only. It measured 1,000 mc. by 1,050 mc.; *i.e.*, only half the size of the mature female. It was colorless, except for the gut, which was black. In this case the body axis could be readily followed. It was 3.5 mm. long. This specimen was fusiform, its greatest diameter, 450 mc., was located at the posterior third of the body, where the bulk of the gut and egg tubes were. The head and a large part of the neck, 0.2 mm., are bent sharply dorsally. The rest of the body then curls tightly ventrally to enclose the head and sharply bent anterior portion. The tail ends sharply in a single point. Its tip is recurved. Egg tubes may be seen in the body cavity, but they contain no ova. (Plate IV, fig. 9.)

The third female measured 9 mm. in length. This was ascertained by flattening out a small female and forcibly with needles straightening out the coils. The body varies in width. Its greatest diameter is 600 mc. It can now be seen that the body cavity bulges out into expansions at several points. The approximation of these expansions to each other, together with a coincident coiling of the parasite, could easily result in the pumpkin-shaped organism so commonly described. The distortion here produced, however, precludes a positive statement in regard to an habitual and orderly arrangement of these expansions along the body axis in the living animal.

The fourth female in order of maturity contained mature ova (coiled embryo visible). It was chosen because it was not tightly coiled. It was examined in glycerine with a stereoscopic microscope. No cover-glass was used, thus eliminating pressure artefact. A wax model was made by combining drawings and direct observation.

The rigidity of the coils in the unfixed female raised the question

whether this was a permanent or a changeable arrangement. It has been already remarked that even in a very young female, where the anlage of the organs was not yet prominent, there was a disposition (as evidenced by angulations) to coil. This same early disposition is also noted in the half-grown specimen which was tightly coiled in one plane. These facts seemed to argue the coiling as a peculiarity of the species.

To shed further light on the subject, reconstructions were made of two mature females after the wax-plate method of Bonn, and a third (partial) reconstruction in pasteboard. In all three the coils were very tight. In two specimens the head and tail project at opposite sides of the coiled worm. In a third the head and tail are close together. In the two complete reconstructions the tail recurves in a direction opposite to the general direction of the coils. That is, tracing the coils in a spiral manner down from the head—either clockwise or contraclockwise, as the case may be—we suddenly come to an abrupt bend toward the tail, where it bends around in the opposite direction. This peculiarity is also seen in the half-grown female mentioned before, and it is this reversal which led to the uncertainty in determining the arrangement by direct examination. As stated above, the coils may (looking at the specimen head on) run clockwise or contraclockwise.

From a consideration of the camera lucida drawings of females at different stages of development, along with the wax model and reconstructions, the following deductions are made:

There is a very early "embryonic" propensity for the worm to coil tightly. The arrangement of such coils is not constant, the coils turning either clockwise or contraclockwise. The head along with a short anterior portion is always bent more or less sharply dorsally. The caudal extremity always twists suddenly in a direction reverse to that of the more anterior coils. As the female becomes mature, the remarkable egg content causes a broadening of the worm without a proportionate increase in length. This causes the mass to appear globular. The pressure incident to such enormous egg content obliterates any "dead spaces" between the coils (internally or externally), and this tends all the more to perfect the globular appearance.

It is presumed (in the absence of direct observation of living specimens) that the worm may alter its coils and protrude head or tail into the lumen of the proventricle. It does not seem probable, from its bulkiness, that the mature female migrates as does *Spirop-*

tera incerta. In support of this, the microscopical sections do not show necrosis as in spiropteriasis, and we do not think that the worms cause serious disease. The female certainly extracts hemoglobin from the host, but does not seem to be wasteful as in uncinariasis. The cagemate of this bird, which is living and also infested, appears perfectly healthy, and is standing such minor blood loss very well.

The Male.—From the fact that the specimens were found only after teasing the mucosa (not at all in the luminal slime), it is presumed that they live in the same situations as the females—in the crypts of the proventricular glands. This is, however, hard to prove, on account of the small size, translucency, and relatively small number of males. Serial sections might or might not, from this last circumstance, include a male.

The largest male measures 6 mm. in length. At its widest part it measures 125 mc. The body is subcylindrical, filiform, tapering anteriorly to end rather abruptly in a rounded extremity. The head is not separable from the body. It tapers more gracefully posteriorly, ending in a tail which is curved strongly toward the cloaca. Tip of tail is sharp, recurved from cloaca after the fashion of the point of a fish-hook robbed of its barb. Cuticle finely striated transversely, thin, transparent. (Plate IV, figs. 1 and 2.)

None of the male specimens display the blood-red color so conspicuous in the female.

The oral opening is circular. It leads to a narrow buccal cavity, which abruptly opens into an œsophagus with thick circularly disposed musculature. This is succeeded by a straight, simple intestine, which becomes coiled at its posterior third, to end 300 mc. from the caudal tip. Cloacal opening surrounded by a pouting, prominent cuticular ring.

Spicules unequal. The shorter measures 150 mc. The longer measures 5,400 mc. in length, and when retracted extends to within 600 mc. of the anterior extremity. This spicule is, then, nine-tenths as long as the individual. One specimen was projected to a distance of 3.0 mm. This length does not represent the full extent to which it may project, as a part of the spicule had been broken off. There are two pairs of preanal and two pairs of postanal papillæ. There is no bursa.

Tropidocerca contorta n. sp.

This worm falls easily into the genus *Tropisuris* (Diesing), later changed to *Tropidocerca*. This genus includes numerous worms which

lie in the proventricles of birds. They vary in size, in different species, from 2 to 7 mm. in length. The striking peculiarity of this nematode is the subglobular form and blood-red color of the female. From the upper pole of the worm a short head projects and from the lower a short tail.[2]

I have found the following species described as infesting the hooded crow, snipe, plover, woodcock, goose, black coot, widgeon, grosbeak, seagull: *Tropidocerca fississpina* (Schlatthauber), *T. paradoxa* (Diesing), *T. gynæcophila* (Molin), *T. bispinosa* (Molin), *T. globosa* (V. Linstow), *T. inermis* (V. Linstow), *T. tenuis* (Lieberkühn), *T. certa* (Leidy).

Upon referring to these species I find that the structure of the mouth and tail parts conforms closely to the worm I have been studying. There are certain marked differences, however, which seem sufficient to warrant the naming of a new species:

1. Its tightly coiled form, which is not mentioned or figured in any of the other species.
2. Absence of the four equidistant longitudinal muscular bands which by contracting give the subglobular shape of other Tropidocercæ.
3. The remarkable length of the longer spicule of the male.
4. Disposition of the male papillæ.

Believing the first-named difference to be the most striking, I have given the name *contorta* to the species.

Trichocephalus dispar (Rudolphi).

From the large intestine of a *Rhesus macaque* (P. Z. G. No. 2,744) three mature worms were obtained. They were very firmly attached to the mucosa and more deeply imbedded than it is customary to find them. The specimen showed tightly clinging detritus along the anterior attenuated portion which could not be removed with a brush. The case is of value because this helminthiasis was associated with a purulent peritonitis. The text-book descriptions do not assign any marked pathogenic properties to this worm. It would seem hypercritical in this case to argue that such association is a mere coincidence. *Tricocephalus dispar* has also been found in *Pithecus satyrus, Cercopithecus mona, C. potas, and C. sabæus, Innuus erythryacus, I. ecaudatus, Cyanocephalus sphinx,* and *C. porcarius* and in *Mycetes seniculus.* It is mentioned as *Tricocephalus lemuris* (Rud.) and *T. palæformis* by Raillet. Its occurrence in

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[2] Diesing, *Syst. Helminth.*, II, p. 207.

these animals suggests lines of transmission from one host to another.

Microscopically, all three worms were found to be females. Two were perfect. Head is missing from the third, suggesting that it was firmly attached to the mucosa. The worms conform in every respect to the accepted generic descriptions of *Tricocephalus*. The two perfect specimens measure each 27 mm. in length. The posterior portion is 8.5 mm. long, the narrow, more attenuated, anterior portion, including the head, 18.5 mm. This gives a close proportion of one to two. Measurements were made of ova which lay in the oviduct close to the vulvar opening. They are 23–25 mc. broad and 52–55 mc. long, including the button.

It is unfortunate that no males were included in the material, since it is by these alone that the species may be surely determined; sexual apparatus (especially the sheath of the spicule) furnishing the differentiating characteristics.

As far as the material goes, this might easily be a specimen of *Trichocephalus dispar*. The ova are almost identical, measuring for the largest specimens 25 by 55 mc. as against 23 by 53 for *T. dispar*. It is true that the specimens are smaller, measuring 27 mm. in length as against 35 mm. for *T. dispar*, but this is not an uncommon variation for identical species in different hosts. (Witness *Ascaris mystax* in cats and lions.) Neither does the size of the eggs conform to that given for other species of *Trichocephalus: crenatus*, 52 by 56, from pig; *affinis*, ? by 65, from horse; *felis*, 36 by 72, from cat; *unguiculatus*, 31 by 52, from rabbit; *depressicollis*, 31 by 80, from dog and fox; *serratus*, 39 by 56, from cat.

Paragonimus westermanii (Kerb.).

This parasite has been found in two wild-cats, *Felis rufus*. They lie in cystic dilatations of the bronchi, generally in pairs. An inflammatory zone is present around each focus. There are not more than half a dozen in each cat. The finding has been made the subject of a paper[3] presented before the Philadelphia Pathological Society by Fox, Smith, Rivas, and Weidman, in which it is pointed out that this worm has occurred in San Francisco, St. Louis, Cincinnati, in the Appalachians, and in the Carolinas, whence these cats came. It is the belief of these writers that the parasite will be found oftener in man if it is carefully looked for, and is likely to become more frequent in the United States with the development of our East Indian possessions, where its effects are endemic.

[3] To be published in a medical journal.

The occurrence of this worm in wild-cats on our Atlantic seaboard should be taken note of and remembered if this disease develop here.

Tænia echinococcus (v. Siebold).

This material came from a female Bactrian camel which died in labor from a ruptured uterus.

The cysts were most numerous in the liver, constituting fully half the bulk of that organ. The spleen was also extensively involved, the lungs less so. The largest cysts in the liver were sterile, showing no scolices. The specimens were observed alive, and we were able to see the scolices retract the rostellum when they were irritated.

One of our microscopic specimens shows a scolex insinuating itself between the lamellæ of the wall of the cyst, a circumstance not commonly mentioned in text-books on helminthology.

Tænia marginata (Batsch.).

The opportunity has presented of seeing this parasite in the most important stages of its complicated life cycle. We have seen the mature worm, ovum, and cysticercus.

The strobile or mature worm is the common tapeworm of the dog and wolf. Its head is provided with a circle of hooklets. Our specimen was obtained from a gray wolf after a vermifuge. The terminal segments are the mature ones and furnish ova to the stools. In these eggs six hooks can be seen, the precursors of the future rostellum of the mature worm. These eggs, if ingested by herbivorous animals, hatch in the intestine and burrow through the liver to the serous cavities of the intermediate host (a ruminant), where they develop a caudal segment. This segment is cystic, and into it on a long narrow neck the head is invaginated. This stage is known as the cysticercus stage, and the parasite has been named *Cysticercus tenuicollis*. We have found these cysts in the Angora goats, woolless sheep, ring-tailed lemurs, Mexican deer, European roe deer, mule deer, red deer, and fallow deer. It has been proven experimentally by several investigators that they are pathogenic for young ruminants.[4]

The occurrence of so many of the cysts aroused the suspicion that our ruminants might be contracting the disease from the canines, opposite whose dens some of the deer are parked. Two examinations of the dejecta of our canines revealed but three in-

[4] Neumann's *Parasites and Parasitic Diseases of the Domesticated Animals*—(Fleming) 1900.

festations out of fifteen animals examined. One of these was an American gray wolf, which was given a vermifuge. As a result segments were obtained corresponding to those of *Tenia marginata.* The wolf has been isolated. He could easily have been the source of some of the cases. In others, however, the animals had been housed in a distant building or were newly arrived. They were doubtless infested when they arrived.

One of our cases has furnished a monster formation. The cysts usually consist of a single bladder, into which the head is invaginated. By pressing upon such a cyst the head and long narrow neck may be expressed. In the monster forms the cyst is invaginated by a second cyst, and into this second cyst the head is invaginated so that when pressure is applied *two* elongated necks emerge, the innermost bearing the head. The formation is discussed by Railliet, p. 238.

If these cysts be ingested by a canine, the bladder will be destroyed, the head becomes fastened to the intestinal wall and gives rise ultimately to the strobile, *Tœnia marginata.*

The material which forms the basis of this communication has been obtained from the Garden of the Philadelphia Zoological Society, from the Laboratory of Comparative Pathology of which it is reported. During the work I have often had occasion to confer with Dr. Allen J. Smith. The reconstructions of *Tropidocerca contorta* were only made possible by his generous tender of apparatus and materials from the Department of Comparative Pathology and Tropical Medicine at the University of Pennsylvania. I acknowledge with sincere thanks his freely given advice and criticism.

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Description of Plate IV.

Fig. 1.—Male *Tropidocerca contorta,* with the longer penis projected.
Fig. 2.—Male *T. contorta,* with penis retracted. The root of the longer penis reaches almost to the head.

Fig. 3.—Female *T. contorta.* This is the youngest female found. It tends to coil even at this early stage.

Fig. 4.—Female *T. contorta.* A mature specimen, showing the cuticular expansions and subglobular form of this nematode.

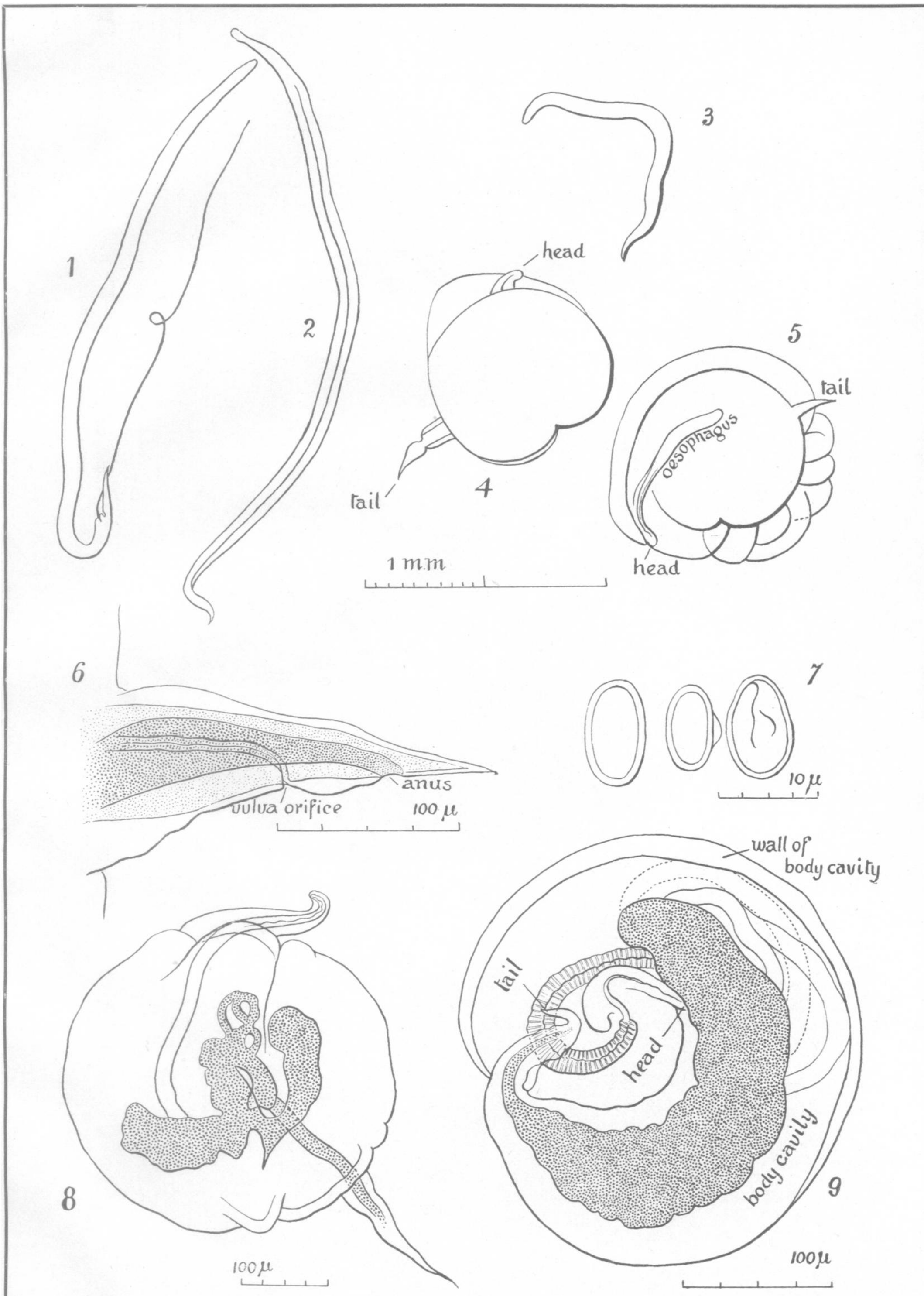
Fig. 5.—Female *T. contorta.* A mature specimen showing the same general features as the preceding.

Fig. 6.—Tail of female *T. contorta.*

Fig. 7.—Ova of *T. contorta.* The unilateral bib is represented on one.

Fig. 8.—Female *T. contorta.* A mature specimen, showing course of œsophagus and intestines.

Fig. 9.—Female *T. contorta.* This is a half-grown specimen. It is coiled in one plane only, and shows the head bent sharply dorsally. It also shows the constant feature revealed in the wax reconstructions, viz., the caudal portion bends sharply in a direction opposite to the general coiling of the worm. This figure is drawn on a much larger scale than the preceding.



WEIDMAN: METAZOAN PARASITES.